Research on Characteristics of Airline Network Based on Passenger Flow

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Abstract: To reflect the scale-free characteristics of airline network, generating n city nodes randomly while the degree distribution exponent is located between 1 and 3, by constructing network edges between nodes, calculating the passenger flow of each network edge, building the relationship of fares to node distance and aircraft type to node type, we propose the mathematical model of airline network revenue, total cost and total profit. Finally, we simulate the airline network profit model and analyze the experimental results, which show that: under the influence of the total number of nodes, the number of hub nodes, the capacity of the hub node and fares, the airline network profit changes in a certain regularity with the change of passenger flow.

Keywords: Airline flow, Airline network, Airline profit, Economic characteristics, The degree distribution exponent.

1. INTRODUCTION

The airline network is composed of the essential factors which include airport, airline aircraft, etc., wherein the airport and airline decide the distribution of air transport space and the ground and air support capacity of air transportation, aircraft completes the spatial displacement of passengers and freight through the airline from one airport to another; at the same time, the number of airports and aircrafts is the time evolution, airline will also present dynamics because of the capacity constraints, the budget and the market demand (OD). Airline network belongs to the typical complex system, which has the scale-free connection characteristics [1].

Scale-free network [2] reveals the universality of growth and preferential attachment mechanism in the complex network of self-organization evolution and the importance of power-law. With the appearance of the scale-free network model, there appeared the MoriTanaka method [3], the rate-equation method [4], the master-equation method [5], the numerical calculation method of Markov chain [6, 7], all of which can be used to calculate the distribution of stability degree. The research on the hub node is mainly concentrated in the virus spread in the network, the network robustness and influence of the vulnerability [8-12]. These studies researched network characteristics from the angle of mathematics, and it would not reveal the real world networks phenomenon, therefore there appeared the study of weighted network and space network [7, 13-14], which have been applied in the complexity [7, 15] and optimization theory [16-19] of airline network. The above researches are lack of insufficient consideration of political and economic factors of airline network; they do not well reflect running characteristics of airline network and far away to application.

This paper allows the node among network which is not connected and repeated and a node connecting the others randomly according to the node degree value; as a result, there is no isolated node and no redundant degree value of each node. By constructing the relationship between fares and airline distance, airline passenger flow and airline distance, airplane type and node type, we researched airline network profit changes with the change of airline passenger flow under the influence of the total number of nodes n, the capacity of the hub node, reflecting the economic characteristics of airline network and it is important for the airline to improve the efficiency of transportation, to reduce the transportation cost and to optimize the network design.

2. ESTABLISHMENT OF AIRLINE NETWORK AND ITS PROFIT MODEL

\[ N \text{ (city)} \text{ node } node(s_i, x_i, y_i, K_i, t_i) \text{ and } n \times n \text{ matrix of OD flow } OD_\text{-flow}(s_i, s_j) \text{ were randomly generated.} \]

Wherein, \( s_i \) expresses as the i node \((i = 1,2,3\ldots n)\), The \( x_i \) and \( y_i \) identify the ordinate and abscissa of the i node, \( K_i \) expresses the value of the i node degree, \( t_i \) expresses the kind of the i node \((t_i = 0,1, \text{ if } s_i \text{ is the hub node, } t_i = 1)\); the path between node \( s_i \) and node \( s_j \) can be the direct path \( transfer0(s_i, s_j, d(s_i, s_j)) \) (Wherein, \( d(s_i, s_j) \) expresses the distance of network edge \( s_is_j \)), a once transfer path \( transfer1(s_i, s_m, s_j, d(s_i, s_j)) \) and the secondary transfer path \( transfer2(s_i, s_m, s_s, s_j, d(s_i, s_j)) \); the direct ration as the proportion of the direct path flow \( d_\text{-flow}(s_i, s_j) \) accounted for the node flow \( OD_\text{-flow}(s_i, s_j) \), that is,
the total cost ($t\_\text{cost}(n)$) and profit ($\text{net\_profit}(n)$) of airline network can be expressed as:

\[
t\_\text{revenue}(n) = \sum_{i=1}^{n} \sum_{j=1}^{n} [d\_f(s_i, s_j) \times \text{OD\_p}(s_i, s_j) + t\_f(s_i, s_j) \times \text{transfer\_p}(s_i, s_j)]
\]

\[
c\_\text{cost}(n) = \sum_{i=1}^{n} \sum_{j=1}^{n} \text{linkflow}(s_i, s_j) \times d(s_i, s_j)
\]

\[
s\_\text{cost}(n) = \sum_{i=1}^{n} \sum_{j=1}^{n} \frac{\text{linkflow}(s_i, s_j)}{\text{ap\_t}(u_i)} \times \text{ap\_c}(u_i) \times d(s_i, s_j)
\]

\[
t\_\text{cost}(n) = c\_\text{cost}(n) + s\_\text{cost}(n)
\]

\[
\text{net\_profit}(n) = t\_\text{revenue}(n) - t\_\text{cost}(n)
\]

With the given change rate of airline passenger flow, we researched the relationship between airline network profit and the airline passenger flow while the parameter scenarios are determined, and the technical route is shown in Fig. (1).
and to win more profit. We select the degree distribution a transportation market, besides the existing airlines, they so work

3.1 the randomly generated OD flow are no more than 2500 people, that is OD_flow(s_j)
∈ [0.2500]; In addition, we also give the value of certain variables directly, direct_ration = 0.6; relation_ration = 1.5; transfer_ration = 0.6; dt_m = 0.05; t_m = 0.02; d_m = 0.04; ap_t(u_i) = 350; ap_c(u_i) = 0.001; ap_t(u_i) = 200; ap_c(u_i) = 0.0007.

3.1. The Study of the Relationship Among Airline Network Profit, the Total Numbers of Node, Airline Passenger Flow and Fares

Airlines always look forward to remain invincible in the transportation market, besides the existing airlines, they so actively explore new markets to excavate potential customers and to win more profit. We select the degree distribution exponent r equal to 1.8 (r = 1.8), the hub node number is equal to 6 (k = 6), the network node number (n) is respectively equal to 100, 120, 150, 180, 200 and 250, the maximum times of passenger flow increase is equal to 100 (max runtime = 100), then we researched the airline network profit with the times of passenger flow increase of different kinds of airlines in the given network node number, as shown in Fig. (2).

Fig. (2). shows that when the other variables remain unchanged, there are more network nodes, and more airline network profit. The change of the airline network profit occurs with the redistribution of OD_flow(s_j) and the re-value of direct_ration, which is from 0.6 to 0.7, as shown in Fig. (3).

Fig. (3). shows that the above conclusion of the more network nodes the more airline network profit has not appeared when direct_ration is equal to 0.7 (direct_ration = 0.7), and the airline network profit according to 150 nodes (n = 150) is less than the profit according to 120 network nodes (n = 120). This is because the airline will get high revenue due to more passenger flow of the direct airlines and the more direct flights cost leads to the less passenger flow of the transit airlines. In fact, fares and the proportion of direct airline passenger flow and transit airline passenger flow are inseparable, the above two should be

Fig. (2): The relationship between airline network profit and the increasing times of passenger flow based on the given number of network node.
Fig. (3). The relationship between airline network profit and the increasing times of passenger flow based on the OD flow of network edge.

Fig. (4). The relationship between airline network profit and the increasing times of passenger flow based on the OD flow of network edge and fares.
3.2. The Study of the Relationship between Airline Network Profit and the Capacity of the Hub Node

To describe the capacity of hub node how to impact on the airline network profit, we select the degree distribution exponent $r$ which is equal to 1.8 ($r = 1.8$), the hub node number is equal to 6 ($k = 6$), the degree value of hub node is respectively from $0.2m_d$ to $0.53m_d$ (hub1), from 0 to $m_d$ (hub2), the maximum times of passenger flow increase is equal to 100 ($\text{max runtime} = 100$), then we researched the airline network profit with the times of passenger flow increase of different kinds of airlines in the condition of the given range of the hub node degree value, as shown in Fig. (5).

It can be observed from Fig. (5), when the other variables remain unchanged, the hub node can connect with more nodes if there is no capacity limit on the hub node, as a result, the range of the degree value of network nodes is bigger, the corresponding airline network profit is larger than the profit with the capacity limit on the hub node.

Contrary to the above conclusion of the more nodes, there is more airline network profit when the other variables remain unchanged. If there is no capacity limit on the hub node, airline network profit according to 250 nodes ($n = 250$) will be less than the profit according to 180 network nodes ($n = 180$). From the simulation result, the degree value of hub node is very big, which is equal to 176, 174, 173, 86, 24 and 11, respectively when $n$ is equal to 180 ($n = 180$), this airline network shows more characteristics of the hub-and-spoke airline network, which reflects the motivation about reason why airlines strive to build the hub-and-spoke airline network.

CONCLUSION

This paper focuses on the study of variation of airline network profit with the airline passenger flow changes based on the constraint of factors, such as the number of network nodes.
node, the number of hub node, the passenger flow of network edge, fares and the capacity of network hub node. Although it is based on certain assumptions, we still can obtain some valuable conclusions, for example, the airline network shows more characteristics of the hub-and-spoke airline network while there is no capacity limit on the hub node, but the research does not distinguish which nodes belong to the hub node, which airlines belong to the key routes, besides, it also does not concern about the cost of opening new airlines and the virtual network structure, which is used to meet larger passenger flow, which will be the focus of future study.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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REFERENCES